SMALL-SCALE DREDGING AND DESILTING EQUIPMENT

C.E. Sperling

CONTENTS

SMALL-SCALE DREDGING AND DESILTING EQUIPMENT FOR CANAL MAINTENANCE

1. INTRODUCTION

This paper deals with small-scale dredging equipment used for canal maintenance, "small-scale" then referring to the size of the equipment and not necessarily to the magnitude of the maintenance works or projects in which it is used. The large dredging equipment, generally used off-shore, is not the subject matter of this paper.

The water management and maintenance of canal systems has a long standing tradition in The Netherlands. In the Middle Ages and even up to the last century most of the maintenance was done manually, using for instance the dredging bow, notorious for breaking peoples' backs. Development of hydraulic and mechanical small dredging equipment, for use in maintenance of canal systems, really started during the second half of this century only.

The various types of equipment now available are summarized in Section 2. Basically one can distinguish two types of equipment: cutter suction equipment, largely hydro-mechanically operated, and the digging type equipment, generally mechanically operated. In Sections 2 and 3 some considerations are given on both types of equipment, including criteria for selection of suitable equipment for different types of maintenance.
Part of the paper also deals with the mechanical digging equipment, mainly of the floating or amphibious type, as manufactured by Konijn BV, The Netherlands.

Sizes of the equipment discussed here are generally limited to widths between 2 and 4 m, drafts of less than 0.8 m and a clearance height (under passages) of maximum 1 m. For silt removal, hydraulic transportation through pipelines can be used, but the material can also be disposed of into elevator barges with a hopper capacity of 7-30 m^3, small pusher crafts and dumpers for further disposal by road transport.

A general characteristic of the small dredging equipment is the high flexibility of application possibilities, among others because of the various possible accessories, available as attachments to the main equipment.

2. TYPES OF SMALL DREDGING EQUIPMENT

Development of small mechanized dredging equipment started only around 1950. The first equipment, a small suction dredger, was actually not more than a rowing boat provided with truck engine and a pump. Usually this was applied in rural areas and the silt was disposed of directly on the adjacent areas.
Since then, several types of equipment were developed which could be broadly classified as "cutter suction equipment" and "digging type equipment".

The first type of equipment cuts the bed material, which is then sucked and pumped away, either over a long distance by means of pumps and pipelines, or locally on the sides, or into a barge or container. The second type of equipment consists of various crane types with different attachments, which can be divided into:

- the hydraulic crawler crane (excavator), equipped with a bucket or a hydraulically operated clamshell;
- a hydraulic grab crane on tires or tracks, provided with a cable clamshell or a dragline bucket.

Both perform the work by means of digging, and they can normally be used for all kinds of work. The hydraulic grab crane with clamshell or dragline is primarily meant for digging of peat and mud. Its use on sandy or clayey bottoms can be limited. The grab crane for a long time had the advantage of a longer reach, usually 11-13 m. Gradually, however, excavators have been developed with longer arms, now even up to 18 m, which has further increased the popularity of the excavator.

The cutter type work is always done from the water, whereas the cranes can work from the side as well as from the water, by mounting them on a pontoon. Gradually, amphibious equipment has been developed as well, to enable passing of culverts, bridges, etc. in the watercourse.

Most of the work on amphibious equipment was done by Konijn BV, from time to time in cooperation with IHC Holland, a company famous in the world of large dredging equipment. Developments in small cutter suction dredgers was largely done by another Dutch company, Klip BV. This was mainly serving the national market, for their own use as a contractor. Some other companies as developed specific small equipment as well.

Floating bulldozers form a special type of digging (or pushing) equipment, able to push the mud from inaccessible places to locations where a simple grab crane can transfer it into a transport medium.

Finally it is mentioned that some of the equipment by Herder BV, as described in the paper by den Herder, can also be used, though on a limited scale, for small shaping or dredging work.

3. IMPORTANT FACTORS FOR EQUIPMENT SELECTION

For the selection of the appropriate equipment for a certain purpose, various factors have to be taken into consideration, apart of course from cost aspects. One important factor usually is the possibilities or constraints related to the disposal of the removed bed material.

If the material cannot be put alongside the canal, it has to be put into a truck, barge, or container, or otherwise to be pumped away to another place through a pipeline.
When the material has to be pumped, a pipeline of 250 mm maximum is mostly used. A larger diameter would to be too heavy for manual operation. A small suction dredger is generally able to pump the silt over a distance of about three kilometres, also depending on the elevation (1 m elevation can be taken equivalent to approximately 100 m horizontal distance).

When sand is pumped, the maximum distance is reduced to about 1 km only. Booster stations could be installed on the pipeline for transport over longer distances, but this is expensive and affects the efficiency of the total transportation line. Of course, provisions have to be made to avoid entering of wood, plastic or other rubbish as car tires, stones, etc.

When there is much of such material, or when silt or sand has to be transported over longer distances, other dredging and transportation means have to be selected. Dredging then usually is of the digging type and transportation can take place by barges, containers, trucks, etc.

Another important consideration in the selection of equipment is the accessibility of the canal. In this respect two types of equipment are available: "from the sides" or "from the water".
Execution of maintenance from the side of the canal is possible when there is sufficient space (maintenance path or road) and when the width of the canal is limited. But another condition is that either direct transportation or dumping of the silt behind the canal bank must be possible.

Where these conditions are not fulfilled, the use of floating equipment (either

boat or amphibious) is appropriate. This equipment is usually of the digging type, in combination with elevator barges and pushers. From the barges the silt can be dumped directly into a watertight container by means of a (land- or pontoon based) grab crane.
Another practice used in the Netherlands is the use of split barges, which can dump the material in other locations (for instance in deeper water), but this will not be applicable in the common Indian canal systems.
Use of a specially designed floating bulldozer was already mentioned in the previous Section.

Maintenance "from the side", with cranes as discussed above is not further dealt with in this paper. It is a relatively straightforward method, for which a large variety of equipment has been developed all over the world. The present paper further concentrates on work "from the water", partly by amphibious equipment.

4. KONIJN SMALL SUCTION DREDGERS (S-SERIES)

The S-series machines (see Figure 1 for an example) all employ a milling suction system, developed in The Netherlands over the past 15 years, especially for dredging of soft silt. The system uses the pumping principle rather than the excavation principle.
The milling cutter suction system consists of:

- A milling cutter scoop for moving the silt or loose deposits towards the suction opening, thereby enhancing the solids/water ratio.
- A milling cutter device for cutting vegetation, (small) branches, small hard pieces of deposits, etc., at the same time mixing the components into an even mixture, for better pump performance.
- A special pump with an impeller which is able to handle relatively large pieces of debris such as cans, bricks, shoes, etc, thereby minimizing clogging of the pump and subsequent down-time.

All this is mounted on a small boat. Dredging is done by winching the boat forward along a guiding cable. On the bigger S-200, additional steering facility is provided by a disc-wheel on its rear legs.

The S-series can be provided with three or four legs (as is shown in Figure 1), so that they can "turtle-walk" on their own power from the transport vehicle into the water, or around small bridges or other obstacles. The principle characteristics of the equipment are as given in Table 1.

Figure 1. Amphidredge S-series

Figure 2. Amphidredge H-series

Table 1. .. Characteristics of S-series

			S-170	S-200
Max. dredging depth	- forward	(m)	3.20	3.50
	- backward (m)	(m)	5.00	5.35
Production		(m3/hr)	50-80	100-140
Diameter suction pipe		(mm)	170	200
Engine power		(Hp)	110	165

Due to the absence of fast moving parts the small dredging boat has proved to be very suitable for work in lined canals. In most cases, the S-series equipment provide an adequate and economical solution. H-series or M-series are more appropriate under the following conditions:
- when there is too much debris or heavy vegetation;
- when the spoil can be pumped directly on the land, so that no extra transporting facilities are needed.

5. KONIJN AMPHIDREDGE H-TYPE

Equipment in the H-series is amphibious in the full sense of the word, since it can move itself from the bank into the water and vice-versa.
Machines in this series consist of the following components:
- A main pontoon (sometimes with supporting side-pontoons);
- 3 or 4 movable legs, hydraulically operated, permitting movement of the machine by crawling (like a turtle). These legs also serve to stand firmly during dredging/excavating.
- A hydraulically operated crane, fixed on the pontoon, with backhoe or dragline bucket.

The patented equipment can work on flat land, in undulating terrain, in swamps and in the water and it can be used on any kind of soil.
The models equipped with four legs (see Figure 2) can move over steep elevations and on steep banks, tc reach the actual work site. The models with three legs are somewhat restricted in that respect.

The four-leg machine can put itself from and onto a truck, since the main pontoon can be raised, after which the truck can drive away underneath the

pontoon. The tree-leg machine can be loaded or unloaded in a similar way with the help of a winch mounted on the machine and serving as a fourth support. Being on a truck the legs of both machines can be swivelled to provide for convenient transport.
Matching auxiliary equipment such as extra side pontoons for stability, winches, etc. is also available. The principle characteristics of the H400-4 model are summarized in Table 2.

Table 2. Characteristics of H400-4

Number of legs	4
Maximum reach of excavator	6.70 m
Maximum dredging depth	4.50 m
Engine	88 Hp
Weight	14 t
Standard backhoe content	500 l
Minimum canal width	2.60 m
Minimum water depth for operating	1.05 m
Minimum water depth for navigating	nil

6. KONIJN AMPHIDREDGE M-SERIES

The M-series encompass crane-pontoon combinations, consisting of the following components:
- Self-powered mobile grab crane, that can operate from the banks and from the water, when installed on a pontoon.
- A special pontoon construction, to carry the crane when this has to work from the water. The crane itself is used to put the pontoon into and out of the water, from and onto a truck. The pontoon is designed to allow the crane to embark and disembark on its own power. The pontoon can be stabilized by extra side-pontoons, being fixed to the main pontoon by locking devices.
- Auxiliary equipment like barges, split-barges and matching push-boats are available.

The principal characteristics of these machines are depicted in Table 3.

Table 3. Characteristics of M-series

Length of standard boom	11.00 m
Engine	31.5 Hp
Total weight	17 t
Standard grab content	600 l
Minimum water depth	0.60 m
Minimum canal width	4.80 m

Although the unique feature of this equipment is the patented method of embarking and disembarking of the crane, two other features are interesting as well:

- the special crane is the most popular of its size and type in Europe, due to its reliability and high capacity;
- the weights and dimensions of crane and pontoon provide for easy transport by truck, as well as for navigation.

The M-series typically are used for dredging of silt and vegetation. As said before, it is less suitable for work in hard soils, because of the use of clamshell or dragline bucket. The advantage of these machines is their long booms, of 10-11 m long. This means that they have the capacity to dispose the material further on the land or into spoil dump trucks directly.
Positioning of the machine can be done by means of cables or with a spud installation. When operating in canals which are also used for navigation, the cable-winch installation can be provided with extra cable outriggers which allows boats to pass the wires.
The mobile crane can of course also be used separately on the land.

7. KONIJN AMPHIDREDGE FLOATING BULLDOZERS (FB)

The FB-Amphidredge (see Figure 3) consists of the following components:

- A main pontoon (supported by side pontoons, if necessary), with diesel engine, winches and a control panel;
- A front-mounted dozer blade, consisting of a central section and two hydraulically operated, movable side blades. The depth of the blades can be adjusted hydraulically.

- A rear-mounted "rudder" system (for stabilizing and steering), consisting of a hydraulically operated arm and twin wheels.

The one man operated floating bulldozer (FB) is appropriate for conditions where a long and straight watercourse cannot be dredged from the banks. In winding watercourses or short stretches it is less convenient. It pushes the silt, layer by layer, together with possible vegetation and debris, to a place where a crane can be stationed which can take the spoil and puts it into means for further transport. The FB requires no additional equipment.

Figure 3. Floating bulldozer (FB series)

Propulsion of the Konijn FB is done by means of hydraulically operated winches and not by propellers. Thus, floating debris like plastic bags, reed, bottles, etc will not disturb the operation. Another advantage is that the machine can easily pass underneath bridges, etc. For extremely low passages it is possible to dismantle the all-weather proof operator's cabin in some minutes. For navigation a draft of only 80 cm is required.

Each machine can be provided with two permanent transport wheels with solid tires on the front of the main pontoon. Transport wheels can be mounted on the hydraulically operated rear wheel leg for launching as well as for short distance travel over land. All bulldozers are provided with a Deutz air-cooled diesel engine which give reliable performance under tropical conditions.

The bulldozer allows for accurate dredging and when working in lined canals, the blade can be provided with small wheels to avoid damage to the lining.

8. COSTS AND CONCLUSIONS

Price indications for the above equipment are given in Table 4 (in US $):

Table 4. Price indications for Konijn equipment

Hydraulic crane	150,000
Grab crane	120,000
Cutter suction dredger	350,000
Amphibious excavator H-type	250,000
M - series	220,000
Floating bulldozer	175,000

Costs of dredging work using this equipment can not be given in general terms. With varying circumstances, they can vary in The Netherlands from 0.75 US$/m^3 to 25 US$/m^3.

Capacities of the various equipment are difficult to give, because they vary widely with the local conditions. Not only the amount and type of soil, vegetation and debris of course strongly affects the performance. But also, the costs of the disposal of the spoil can be a substantial part of the total costs and vary with the quantities to be removed, with the methods used (pumping, containers, trucks, etc) and certainly with the distance over which the material has to be transported.
Consequently, it is difficult to give general cost figures for the operational costs. Nevertheless some information on operational aspects is given in Table 5. The last column gives the approximate time required to train the operator for acceptable performance.

Generally, the experience is that the suction dredger provides the cheapest solution. Even with the extensive experience with this equipment in The Netherlands post-project calculations still may differ considerably from the pre-calculated budgets.

Table 5. Some operation and maintenance data

	Fuel cons. (l/hr)	Maintenance (%)	Training (wks)
Hydraulic crane	16	10	2
Grab crane	4	12	4
Cutter suction dredger	25	15	4
Amphibious excavator H-type	8	15	2
M - series	4	15	4
Floating bulldozer	4	10	1

In concluding it can be said that pilot projects are necessary to select the best equipment under certain conditions, and to establish the corresponding costs, especially where the equipment is alternatively introduced for the first time.

DEVELOPMENT OF A CANAL MAINTENANCE POLICY

F.C. Hamster & M. Jurriëns

CONTENTS

DEVELOPMENT OF A CANAL MAINTENANCE POLICY

1. INTRODUCTION

In earlier papers the Dutch institution of the "Waterboard" has been discussed. The present paper deals with the development of a new maintenance plan which became necessary after a merger was planned of two adjacent Waterboards, which was implemented from 1-1-1992.

Both Waterboards were situated in the upper Northeast part of the Netherlands. The former Waterboard "De Veenmarken" covered some 27.000 ha and the Waterboard "Reiderzijlvest" about 65.000 ha; the new combined Waterboard "Dollardzijlvest" (DZV) will thus cover some 92.000 ha.
The larger part of this Waterboard (50.000 ha) is a former peat colony, which was reclaimed from 150 till 50 years ago. The peat from the high moor was used for the heating of houses and for industrial use. Local people built a system of canals and branches for the water control and the transport of the peat. Nowadays it is an agriculture area, with potatoes as main product for the production of starch. The remaining part of the Waterboard area can be divided into sandy soil and clay polders near the sea. The entire Waterboard area (DZV) is in fact one water management system, ultimately draining on the "Dollard", an estuary of the North Sea.

The principal task of both old and new Waterboards is water management, which eventually implies taking all necessary measures needed to regulate the water flows and levels in the canals for the benefit of agricultural and pasture land, but also for nature reserves and built-up areas. The basic task not only concerns the operation of the system, and incidental design and construction of new works, but the maintenance of the systems as well.

For the situation after the merger of the two Waterboards, a new maintenance plan had to be developed, because both Waterboards had a different policy of maintenance and equipment. The merger also evoked the need to adapt the organization. At the same time there is a land consolidation (reallotment) program taking place in the entire area, which offers the possibility to improve maintenance facilities.

For the development of such plan, the following major questions are to be addressed:

implications for the design.
The designer usually is another person than the surveyor of the maintenance works. When the surveyor is doing the work, the designer has already done his job. The designer must take into account what the surveyor has to do, and make sure that he can really do so. Both persons are equally important: a bad design does not work, but dirty ditches and bad maintenance do not work either.

To execute its job, a Waterboard has to maintain many and frequent contacts with farmers and other inhabitants of this area. They are the "customers" and they must be informed about measures to be taken and be convinced of the utility of the Waterboard, being after all a service organization for that area and the inhabitants.

The ultimate performance of a Waterboard depends very much on the daily work of the technical staff, designers and surveyors, which are both in regular and direct contact with the clients. This should be fully appreciated by the Waterboard management.

3. OBJECTIVES AND OBJECTS TO BE MAINTAINED

The objects to maintain are canals, weirs, inlets, culverts, sluices, pumping stations, etc. Also it is important to maintain the necessary buildings, workshops, installations, machinery etc. In this paper emphasis is on the maintenance of canals.

In some Waterboards the farmers have to maintain a part of the canals and the Waterboard checks the results. The DZV Waterboard maintains the water management systems by itself, and the farmers only maintain the ditches between the parcels. For the functioning of the whole system these ditches are very important, nevertheless cleaning of them is a job for the farmers. In case of trouble between farmers, the Waterboard has the possibility of supervision and arbitration. On "information evenings" we explain the working of the system and we show the farmers (slides, graphs, etc) the problems they can expect in case of poor maintenance.

To be sure that the system is always clean and ready for use, the Board has the powers under the law to force an unwilling farmer clean the canals. The bill for the job (by example dredging the canal), including a fine, will be send to the farmer, because he did not meet his obligations (see also the papers by Siefers and Deurloo).

Although the main purpose of water control is that the system must be able to function at any moment, in specific cases we also pay special attention to some other aspects, depending on the area concerned or on other objectives such as:

- Built-up areas (non-agricultural land): it can be desirable to mow more, to get at any time nicely mowed slopes along the canals in built-up areas. Or in contrast, it can be appropriate to mow less to maintain a certain amount of water vegetation;
- Horticulture areas: besides a good water management such areas demand a special attention for the vegetation in and along the canals where it can be a breeding place for harmful insects;
- Recreation: it can be necessary to make some canals fit for large or small boats, anglers, etc. It is possible that those "activities" also ask for a special maintenance approach;
- Environmental aspects: when the dimensions of the canals are large enough, it is possible to maintain or rehabilitate some nice and useful water vegetation;
- Relation with our clients, the farmers: they have to accept our activities and the disposal of removed vegetation. It must be possible to clean the canals without causing trouble or nuisance to the farmers.

At the moment these are the major aspects taken into account in the DZV Waterboard. In other Waterboards, the package of aspects may be different.

4. THE MAINTENANCE EXECUTION

A first choice to be made is on who will be executing the work: a) the Waterboard itself, b) contractors or c) the farmers.
This Section concentrates on maintenance of the main canal system. As outlined in the papers by Siefers and Deurloo, farmers are responsible for the maintenance of the canals directly bordering their lands. For the work on the higher level system, for which farmers have no proper equipment, only the first two possibilities remain. In choosing then, aspects as costs, specialization, control/supervision and flexibility/continuity have to be considered.

Generally, the equipment and operation costs are basically the same for contractors and Waterboard execution. The "Added Value Tax" that has to be paid extra for the contractors renders them more expensive, however. Therefore in many cases Waterboards do the work themselves. Yet, it is a question of "good sports" to work as effectively as possible to realize the maintenance at lower costs than the contractor would ask for the same job.

Another aspect is the specialization. Sometimes the required equipment is that specialized that only a few contractors do have it, and it might be better for the Waterboard to purchase it for own use. This does not apply for special equipment that is required only incidentally, where it is better to call in a contractor for such instances.

With respect to supervision it can be said that the execution by the Waterboard needs less strict supervision. Supervision is done by the Waterboard surveyors; it is their "own" system, for which they are responsible. With a well motivated team, this supervision poses no problems. With contractors, having different interests, more and closer supervision is often necessary.

Regarding aspects as flexibility and continuity it is important to have a continuous employment for the machinery throughout the year, if possible for the different kinds of activities. Biggest part of the equipment costs concern capital costs. The more it stands idle, the more expensive it is. Therefore, if a Waterboard has a too small system to keep the equipment going throughout the year, it may be better to have contractors to do the job.

In DZV Waterboard we have chosen to execute the maintenance by the Waterboard itself, with own personnel and equipment. Main reasons for this are the aspects of cost and supervision as discussed above and the possibilities (given the size of the system) to meet the requirements of specialization and continuity. Only some special activities will be done by contractors, such as incidental dredging by large cranes.

5. CHOICE OF EQUIPMENT

A next important question concerns the choice of the equipment. For the selection of our maintenance equipment we used three criteria:

- capacity of the equipment;
- accessibility along the canals;
- continuity in the use of the equipment.

Of course, these criteria are ultimately related to costs. For costs reasons, no manual maintenance is done in our Waterboard. Moreover, we do not apply chemicals. Not only because of their environmental effects, but also because they destroy the under-water vegetation which is beneficial for the stability of the side slopes and because many plants need a long time to die after chemical spraying. Thus, the maintenance is done entirely with mechanical means. For details on such equipment, see the papers by Hebbink and by den Herder.

When comparing costs for maintenance from the water (boat) with that from the land, the capacity of overland equipment (in our situation) is much higher, because of the good overland accessibility. In DZV Waterboard therefore, no water equipment is used and we have basically opted for tractor mounted equipment.

In our Waterboard total running costs of the equipment costs are generally about Dfl 90 per hour, Dfl 40 for the operation and Dfl 50 for the equipment. It is our experience that there is not much difference in the investment costs between small, but specialized tractors or the standardized bigger tractors. This means that it is possible and advisable to choose the best combination with the highest production per hour.
Moreover, as it is shown for instance in the paper by Hebbink, annual maintenance costs are in the first place determined by the frequency; the cost per maintenance action do not differ that much. This supports the point to select equipment with the highest capacity.

Small tractors cannot always remove all vegetation in one go. Thus, the frequency can be reduced by using large tractors, which at the same time have a high production per hour. Therefore, small tractors are only used where accessibility is insufficient for the large ones.
In all cases, we use combinations of different equipment attached to one tractor to be able to do more actions at the same time.

With regard to the continuity aspect we try to make use of the employees as well as of the machinery throughout the year. The same machinery can be used for different kinds of activities in different periods.
For optimum utilization of the equipment the Waterboard does not possess large equipment and incidental activities that need for instance a large crane are being carried out by a contractor.

Thus, our Waterboard made the basic choice for normal standardized agriculture tractors (2.50 m.). These tractors can be used for mowing activities as well as for normal dredging activities, by applying different combinations:

- Tractor with one mowing machine (a 3 m flail mower), front end mounted, for mowing the grass strips and with another mowing machine attached at the rear, for the mowing of the banks. This enables cutting the grass in both places and removing the grass from the banks, all in one go.
- Tractor with a mowing machine (a fingerbar) and a rake attached for the

removing of underwater vegetation.
- Tractor with a flail mower, attached with a long beam, for mowing of long banks, too long for the aforementioned machines. We use this machine also for the mowing of banks on the other side of a canal and along roads without a grass strip.

To prevent rottening of grass and vegetation disposed on the slopes, we remove it and throw it on the grass strips or on the fallow parcels (after harvest). In winter, the same tractors are then provided with a dumper instead of the mowers, to spread or remove the vegetation, where necessary. In larger and wider canals, the vegetation is removed with the aforementioned crane with a beam of 11.50 m. and a mowing bucket attached.

Besides these activities of small maintenance we sometimes have to reshape the canal and restore side slopes. For this purpose the same tractors and cranes are being used, but attached with other implements such as a screw and a rotary cultivator.

6. DESIGN ASPECTS AND DATA BASE

In design of new works, requirements of future maintenance are taken into account, according to the criteria outlined earlier.
First of all there is the trade off between investment in design and lay-out against maintenance costs during many subsequent years. For instance, a canal with over-dimensioned profile costs less in maintenance than a smaller profile, precisely fitting the hydraulic design. Therefore we apply a certain over-dimension in the smaller canals, where a lower frequency of maintenance is desirable and in which the functions are relatively less affected by the vegetation.

Furthermore the following aspects are incorporated in design:
- Three meter wide grass strips are provided and kept free along the canals;
- Every canal is connected with the higher order canal with a 5 m wide culvert, for accessibility for maintenance.

Obviously this practice costs land. Basically, it is a question of calculation, weighing the benefits of more effective maintenance against the price of the land. But of course there is also an emotional aspect. Apart from the aspect of ownership ("this land is mine") felt by the farmer, it is sometimes felt that the land could better be used for agricultural production than for maintenance. In situations with local shortage of land, the policy can therefore be different.

The importance of a database has been mentioned earlier. In our Waterboard we are now improving the database, in order to make it appropriate for the application of hydraulic models. Use of these models would serve the operation (calculation of flows and levels), as well as the maintenance, for instance by assessing the effects of vegetation, profile shapes, etc.

7. ORGANIZATIONAL SET-UP

The opportunity of the merger of the two Waterboards was used to modify the organizational set-up. The new office of the Waterboard is now divided into six sections, under two distinct departments:

The two departments each have a managing director, and together with the six sectional heads they look after the daily management. Apart from this, there is a Board of twenty-eight persons, called the General Committee, in which the farmers (land inhabitants) and the urban inhabitants are being represented. Besides that there is an Executive Board of seven persons (Executive Committee), selected out of the General Committee.

Administrative section Financial section Personnel affairs	Administrative affairs Dpt.
Design and construction Water management Maintenance	Technical affairs Dpt.

The maintenance team forms one of the six sections. The head of this section is responsible for all maintenance in the Waterboard area. He has a budget for his activities and manages his section in close coordination with the heads of the water management section and of the financial section.

Regionally, the Waterboard is divided into two districts, with one surveyor in every district. Both districts have a number of tractor drivers, some crane drivers and some manual labour. To support this maintenance team both districts have a workshop with some technicians for the maintenance of the machinery.
The surveyor is an important man. He sees and hears a lot in his district and he

is in frequent contact with farmers. The image of the Waterboard largely depends on the quality of the surveyors and their teams.

8. SUMMARY AND DISCUSSION

In developing a maintenance policy, the following issues are to be addressed:
- A complete data base of the objects to be maintained;
- A clear formulation of the maintenance objectives;
- A policy on who is to execute the works: the farmers, the Waterboard itself, or contractors. Elements involved are, besides of course the costs, the required specialized equipment, aspects of supervision and control and of flexibility and continuity.
- The composition of the equipment package to be used, selected on the basis of clear criteria as for instance costs, capacity, accessibility and continuity.

For the newly formed Dollardzijlvest Waterboard, maintenance is done by the Waterboard itself, because it is cheaper, easier to supervise and because the system is large enough to justify the employment of own equipment and corresponding team.
The equipment is selected such as to have maximum capacities, reducing the frequency as well as the cost per hour. Also the equipment is such that (part of) it can be used for varying purposes, thus guaranteeing its intensive and continuous use. Altogether, the maintenance execution is based on the principle of "moving fast with large capacities and flexible means".

Where possible and appropriate, maintenance aspects should be incorporated in the design of new parts of the water control system. In DZV Waterboard this is done for instance by giving the canals some over-dimension and by providing grass strips, culverts, and adequate maintenance paths.
For an effective planning of maintenance, it is important to have a complete and consistent data base of the system. Hydraulic models can then be applied to assess the effects of various measures.

It has to be seen to what extent the above can be useful in the Indian context. The gist of this paper is to emphasize the importance of a systematic approach in developing a maintenance policy, and to outline the issues to be addressed and the criteria to apply. As such, it may have a more general validity. But the execution methodology in India will of course be different. The application of mechanical equipment for instance, may remain limited for some time to come. Where it is required, the above considerations may be helpful.